EFFECTS OF FIXED-INTERVAL SCHEDULE AND REINFORCER DURATION ON RESPONDING REINFORCED BY THE OPPORTUNITY TO RUN

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Two experiments investigated the effects of schedule value and reinforcer duration on responding for the opportunity to run on fixed-interval (FI) schedules in rats. In the first experiment, 8 male Wistar rats were exposed to FI 15-s, 30-s, and 60-s schedules of wheel-running reinforcement. The operant was lever pressing, and the consequence was the opportunity to run for 60 s. In the second experiment, 8 male Long-Evans rats were exposed to reinforcer durations of 15 s, 30 s, and 90 s. The schedule of reinforcement was an FI 60-s schedule. Results showed that postreinforcement pause and wheel-running rates varied systematically with reinforcer duration but not schedule value. Local lever-pressing rates decreased with reinforcer duration. Overall lever-pressing rates decreased with reinforcer duration but increased with schedule value. Although the reinforcer-duration effect is consistent with previous research, the lack a schedule effect appears to be the result of long postreinforcement pauses following wheel-running reinforcement that render the manipulation of the interval requirement ineffective.

Key words: fixed-interval schedule, reinforcer duration, wheel running, lever press, rats

Although Kagan and Berkun first demonstrated that running can serve as a reinforcing consequence for an instrumental response in 1954, the reinforcing properties of running have not been as extensively investigated as those of commonly used reinforcers such as food and water. Of the investigations that have occurred, most used ratio (Collier & Hirsch, 1971; Iversen, 1993; Pierce, Epling, & Boer, 1986; Premack, 1963, 1965; Premack, Schaeffer, & Hundt, 1964) rather than interval schedules of reinforcement (Iversen, 1993; Kagan & Berkun, 1954). On fixed-ratio (FR) schedules of wheel-running reinforcement, postreinforcement pause (PRP) duration and bar pressing rate increased as the schedule value increased, while the frequency of reinforcement decreased (Collier & Hirsch, 1971; Premack et al., 1964). Based on these observations, Collier and Hirsch stated that, ''these results are similar in all respects to those reported when food or water are used as reinforcers for ratio schedules'' (p.

159). Consequently, Collier and Hirsch concluded that running generates schedule effects similar to those generated by commonly used reinforcers.

This conclusion is premature, given that wheel-running reinforcement has not been investigated over the same types of schedules and ranges of schedule values as have food and water reinforcement. In a recent investigation of the reinforcing properties of running, Belke (1997) noted that during training, mean PRP duration remained unusually long (e.g., ranging from 20 to 40 s) on schedules that typically generate high response rates and short PRPs (e.g., variable-ratio [VR] 3, VR 5). Based on this observation, Belke and Heyman (1994) and Belke (1997) used response-initiated interval schedules (i.e., tandem FR 1 variable-interval [VI] schedules) to investigate the effects of interreinforcement interval and reinforcer duration on lever pressing for the opportunity to run. Response-initiated schedules were used to prevent long PRPs from affecting response rates on interval schedules with short interreinforcement intervals.

These long PRPs may reflect an inhibitory aftereffect of reinforcement that varies with the duration of reinforcement. This aftereffect may be viewed as a period during which a reinforcer is relatively ineffective, an effect perhaps not unlike momentary satiation.

Such effects probably occur with any kind of reinforcer, and our usual experimental preparations with food or water reinforcers minimize such effects by ensuring that each reinforcer delivery is small in amount or duration relative to total consumption. But with amounts scheduled in the normal environment or with other kinds of reinforcers (such as sexual contact or running), the post-reinforcement inhibitory effects might be substantial. Moreover, such effects are likely to produce different patterns of responding under certain schedules of reinforcement, in particular fixed-interval (FI) schedules, than might be expected on the basis of patterns generated when the reinforcers are small bits of food or water.

A second issue related to the use of response-initiated interval schedules by Belke (1997) and Belke and Heyman (1994) is that the generality of effects of variables such as reinforcer duration on responding for the opportunity to run may be limited by the use of these schedules. Consequently, it is necessary to demonstrate that the same effects occur with reinforcement-initiated rather than response-initiated interval schedules. The present study sought to address these issues by investigating the effects of schedule value and reinforcer duration on running and responding for the opportunity to run on standard FI schedules.

EXPERIMENT 1

Experiment 1 investigated schedule effects on responding for the opportunity to run using FI schedules of reinforcement. Previous investigations (Iversen, 1993; Kagan & Berkun, 1954) used FI schedules that ranged from 120 to 600 s. Although Iversen reported data from schedule values between 10 and 30 s, these data came from single sessions in which the schedule value was being increased in small steps up to an FI 2-min schedule over six sessions. As such, the data do not represent steady-state values. In the present study, subjects were exposed to FI 15-s, 30-s, and 60-s schedules of wheel-running reinforcement.

METHOD

Subjects

Eight male Wistar rats, obtained from Charles River Breeding Laboratories, served as subjects. The animals were approximately 1 year old at the start of the experiment and had previously participated in an operant procedure with the opportunity to run as a reinforcer. The rats were individually housed in standard polycarbonate cages (48 cm by 27 cm by 22 cm) in a holding room on a 12:12 hr light/dark cycle (lights on at 8:00 a.m.). Subjects were maintained at a target weight that was approximately 80% of an initial free-feeding body weight that had been obtained 2 weeks before the start of the previous experiment. Target weights varied between 300 and 306 g. Distilled water was freely available in the home cages.

Apparatus

Subjects were tested in activity wheels (three Wahmann and five LaFayette Instruments Model 86041 A) with diameters of 35.5 cm. Wheels were located in soundproof shells equipped with fans for ventilation and to mask extraneous noise. A retractable lever (Med Associates ENV-112) was mounted at the opening of each wheel. The lever extended 1.8 cm into the chamber through an opening (7 cm by 9 cm) in the center at the base of the wheel frame. A microswitch attached to the wheel frame recorded wheel revolutions. The force required to close the lever microswitches ranged between 18 and 27 g. Lights (24 VDC) mounted on the sides of the wheel frame served to illuminate the inside of the wheel. Control of experimental events and recording of data were handled by IBM personal computers interfaced to the wheels.

Procedure

Thirteen rats obtained from Charles River were given free access to the same running wheel for 30-min sessions each day over a period of 10 days. The number of wheel revolutions was recorded for each rat on each day. After 10 days, the 8 rats with the highest rates of running were selected as subjects. In the next phase, in addition to running each day, lever pressing was shaped in standard operant conditioning chambers. Each lever press produced 0.1 ml of a 15% sucrose solution. When subjects reliably pressed the lever, the schedule of reinforcement was shifted from an FR 1 schedule to a series of VR schedules (i.e., VR 3, VR 5, and VR 10). Each VR schedule was in effect for approximately four ses-

sions, and each session ended when 50 sucrose reinforcers had been obtained.

Throughout the period of lever training, subjects continued to run in the wheels for 30-min sessions before lever training sessions. When lever pressing for sucrose solution appeared to be stable, these sessions were discontinued. At this point, the retractable lever in each wheel chamber was extended during the wheel-running sessions, and the opportunity to run for 60 s was made contingent upon a single lever press. That is, a single lever press caused the lever to retract and the brake to release. Following this, the wheel was free to turn for 60 s. After 60 s, the brake was engaged and the lever was extended. Each session consisted of 30 opportunities to run. The schedule of reinforcement was changed in the following sequence: FR 1, VR 3, VR 5, VR 9, and VR 15. Subjects remained on each schedule for four sessions before advancing to the next schedule.

Following the last day on the VR 15 schedule, the rats were placed on a series of four tandem FR 1 VI schedules as part of another experimental procedure. The reinforcing consequence on these schedules was the opportunity to run for 30 s. Once this other experimental procedure had been completed, the animals were shifted to an FI 30-s schedule of wheel-running reinforcement for the present study. Reinforcer duration was increased to 60 s. As in training, each session was terminated after 30 reinforcement periods.

For the first condition, all animals were exposed to the FI 30-s schedule for 30 sessions. After 30 sessions, the schedule was changed to an FI 60-s schedule for Rats JS2, JS9, JS10, and JS13 and an FI 15-s schedule for Rats JS11, JS12, JS4, and JS5. The rats were exposed to these schedules for 30 sessions. After 30 sessions, rats that had been exposed to an FI 60-s schedule were changed to an FI 15-s schedule, and rats that had been exposed to an FI 15-s schedule were exposed to an FI 60-s schedule. Again, these schedules remained in effect for 30 sessions. Following each session, animals were weighed and fed a measured amount of food to maintain the target body weight. All sessions were conducted between 9:00 a.m. and 2:00 p.m. 7 days a week.

Lever presses, wheel revolutions, and post-reinforcement pauses to the first lever press following the end of the reinforcement period were recorded for each reinforcement and cumulatively for the entire session. Wheel-running rates were calculated as the total number of revolutions divided by the total time during which running could occur, expressed as revolutions per minute. Overall lever-pressing rates for each session were calculated as the total number of lever presses in a session divided by cumulative time between the termination of a reinforcement period and the lever press that produced a subsequent reinforcement. Overall lever-pressing rates were expressed as responses per minute. A median PRP was obtained for the distribution of all PRPs over the last 10 sessions on a reinforcement schedule. Local lever-pressing rate for each session was calculated as the number of lever presses divided by the time spent pressing, exclusive of the PRP. Overall reinforcement rates were calculated in a manner similar to overall lever-pressing rates. Specifically, the total number of reinforcement periods was divided by the cumulative time between the termination of a reinforcement period and the lever press that produced the subsequent reinforcement, and expressed as reinforcers per hour.

RESULTS

Data from the last 10 sessions on each FI schedule were analyzed. Figure 1 shows that mean wheel-running rates did not vary systematically with reinforcement schedule, although the rate of running under the FI 15-s schedule was lower than under the FI 30-s and 60-s schedules. For the group, mean wheel-running rates on the FI 15-s, 30-s, and 60-s schedules were 25.95, 28.40, and 28.83 revolutions per minute, respectively. A repeated measures ANOVA showed a significant effect of interval duration, $F(2, 14) = 9.85$, $p < .01$. Post hoc Dunnett t-test comparisons showed that wheel-running rates on the FI 15-s schedule were significantly lower than those on the FI 30-s schedule, $t_d(14) = 3.55$, $p < .01$, and the FI 60-s schedule, $t_d(14) = 4.08$, $p < .01$.

In contrast to wheel-running rates, overall lever-pressing rates were systematically related to schedule value. Figure 2 shows that the overall rate of lever pressing increased as a function of FI duration for all rats except JS11. JS11's lever-pressing rates were about
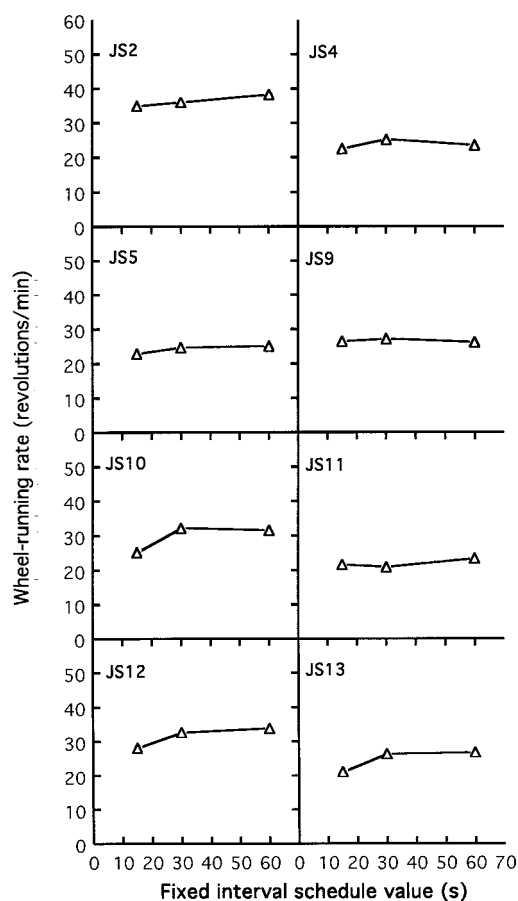
Fig. 1. Mean wheel-running rate (revolutions per minute) as a function of fixed-interval schedule value for each rat. Mean values and standard errors were calculated from the last 10 sessions on each reinforcement schedule. Note that error bars falling within the width of the data point do not appear in this and subsequent plots.
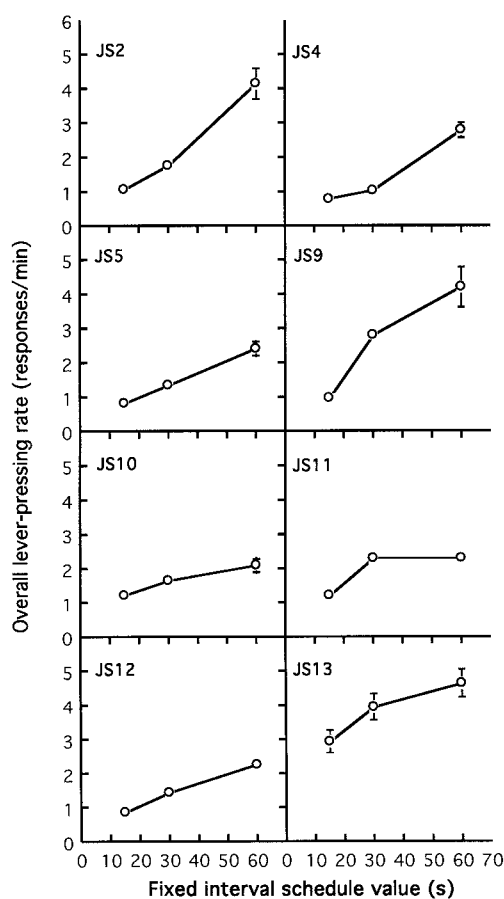
Fig. 2. Mean overall lever-pressing rate (responses per minute) as a function of fixed-interval schedule value for each rat. Mean values and standard errors were calculated from the last 10 sessions on each reinforcement schedule.

the same between the FI 30-s and 60-s schedules. For the group, mean overall lever-pressing rates were 0.98, 1.75, and 2.88 responses per minute for the FI 15-s, 30-s, and 60-s conditions, respectively. A repeated measures ANOVA revealed a significant effect of schedule, $F(2, 14) = 26.81$, $p < .0001$. Post hoc comparisons revealed significant differences in lever-pressing rates between the FI 15-s and FI 30-s schedules, $t_d(14) = 3.11$, $p < .05$, the FI 15-s and FI 60-s schedules, $t_d(14) = 7.30$, $p < .01$, and the FI 30-s and FI 60-s schedules, $t_d(14) = 4.19$, $p < .01$.

Figure 3 shows median PRP as a function of schedule value for each animal. Inspection of the graphs suggests no systematic relation-

ship between PRP and schedule value. Across all animals, the average median PRPs for the FI 15-s, 30-s, and 60-s schedules were 55.90, 50.05, and 60.25 s, respectively. A repeated measures ANOVA revealed a significant effect of schedule value, $F(2, 14) = 4.54$, $p < .05$. Post hoc comparisons showed that the median PRP for the FI 30-s schedule was significantly lower than that for the FI 60-s schedule, $t_d(14) = 3.01$, $p < .05$.

Based on the observation that the median PRP did not vary systematically with schedule value, the percentage of PRPs that were longer than the schedule value was calculated for each rat under each schedule value. Figure 4 shows that this percentage decreased for all animals as the schedule value increased. For
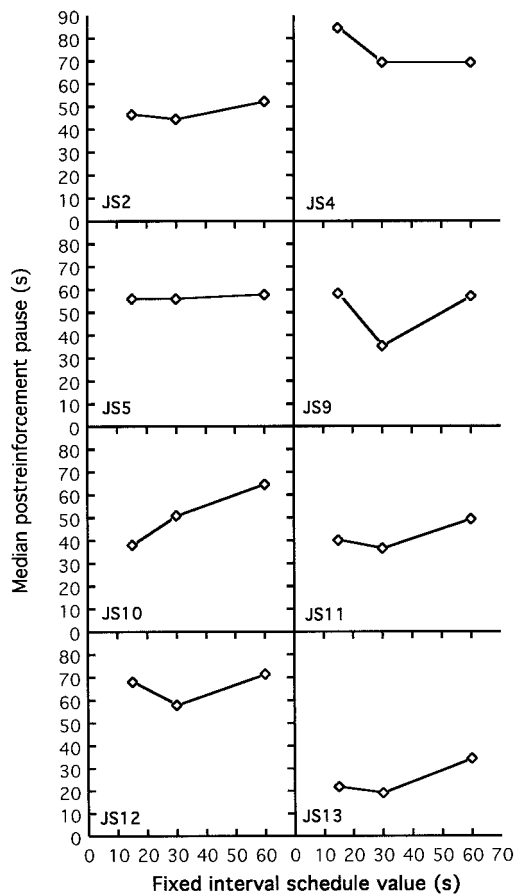
Fig. 3.   Median postreinforcement pause (in seconds) as a function of fixed-interval schedule value for each rat. Median values were obtained for the pooled distribution of pauses from the last 10 sessions on each reinforcement schedule.
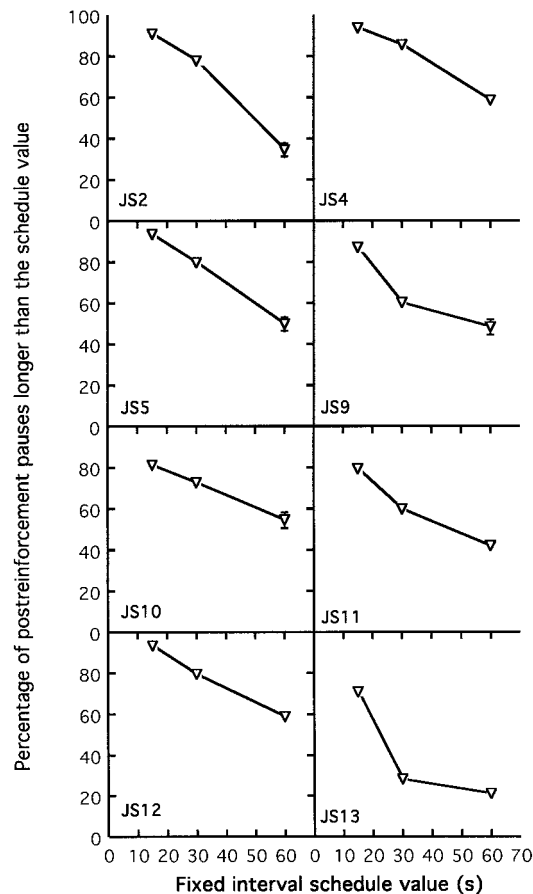
Fig. 4.   Mean percentage of intervals in which the postreinforcement pause was longer than the schedule value as a function of fixed-interval schedule value for each rat. Mean values and standard errors were calculated from the last 10 sessions on each reinforcement schedule.

the group, the mean percentages of PRPs longer than the schedule value were 88.36%, 73.49%, and 49.40% for the FI 15-s, 30-s, and 60-s schedules, respectively. A repeated measures ANOVA showed a significant schedule effect, $F(2, 14) = 55.78$, $p < .0001$. Post hoc Dunnett t-test comparisons showed significant differences in PRPs greater than the schedule value between the FI 15-s and FI 30-s schedules, $t_d(14) = 4.80$, $p < .01$, the FI 15-s and FI 60-s schedules, $t_d(14) = 10.55$, $p < .01$, and between the FI 30-s and FI 60-s schedules, $t_d(14) = 5.75$, $p < .01$.

Local lever-pressing rates were not calculated for these data because the high percentage of PRPs longer than the schedule value would distort the rates. In other words,

when a substantial number of PRPs are longer than the schedule value, the majority of reinforcers are obtained with just a single lever press. Consequently, local lever-pressing rates would be inflated, because these lever presses would increment the number of lever presses in the numerator but not the time spent pressing in the denominator, and as the percentage of reinforcement intervals during a session that are terminated with a single lever press increases, the effect of this inflation increases.

Finally, neither mean overall rates of reinforcement nor session duration varied systematically with changes in schedule value. For the FI 15-s, 30-s, and 60-s schedules, mean

overall rates of reinforcement were 46.40, 53.58, and 38.92 reinforcers per hour. When reinforcer duration (i.e., 60 s) is included in the calculation of overall reinforcement rates, the rates for these three conditions become 26.17, 28.30, and 23.61 reinforcers per hour, respectively. Mean session durations across these conditions were 68.8, 63.6, and 76.3 min, respectively.

DISCUSSION

Previous research with commonly used reinforcers such as food or water has shown that the duration of the PRP for rats and pigeons varies between one third and two thirds of the FI value (Dukich & Lee, 1973; Schneider, 1969; Shull, 1971; Shull & Guilkey, 1976) and that there is an approximately linear relationship between PRP duration and FI schedule (Dukich & Lee, 1973; Harzem, Lowe, & Spencer, 1978; Schneider, 1969; Shull, 1971). In the present study, however, PRPs were considerably longer, often longer than the scheduled FI. The most likely interpretation is that these pauses reflect the inhibitory or satiation-like aftereffects of the reinforcer rather than temporal control by the FI schedule. Indeed, with such pausing one could not expect to observe the kind of response rate and response pattern relationships that are observed under FI schedules when the reinforcers are small bits of food or water. And, in fact, such relations were not observed. For example, PRP duration did not increase with FI duration. Other relations, such as that between overall response rate and FI duration, were likely artifactual in the sense of being due to an increasing, although relatively small, frequency of pauses ending before the end of the FI as the FI duration increased.

EXPERIMENT 2

In light of the results from Experiment 1, Experiment 2 investigated the effects of varying reinforcer duration on response rates and PRP on an FI schedule of wheel-running reinforcement. Belke (1997) showed that wheel-running rates, PRP duration, and local lever-pressing rates varied systematically with reinforcer duration on tandem FR 1 VI 30-s schedules. PRP duration increased as reinforcer duration increased, whereas wheel-

running rates and local lever-pressing rates decreased. The present study sought to determine whether similar effects would be observed on standard rather than response-initiated interval schedules.

METHOD

Subjects and Apparatus

Eight male Long Evans rats, bred in the laboratory from animals obtained from Charles River, served as subjects. The animals were approximately 1 year old at the beginning of the experiment. Prior to participating in the present study, the subjects had been exposed to operant procedures with the opportunity to run as a reinforcing consequence. All rats were housed individually in standard plastic cages (48 cm by 27 cm by 22 cm) in holding rooms on a 12:12 hr light/dark cycle (lights on from 8:00 a.m. to 8:00 p.m.). Immediately after each daily experimental session, the rats were weighed and fed a measured amount of food to maintain them at a target body weight that was 80% of an initial free-feeding weight that had been determined when the subjects were approximately 3 months old. The target body weights ranged from 290 to 311 g. Distilled water was available ad lib in the home cage.

The apparatus described in Experiment 1 was used in Experiment 2.

Procedure

The training procedure described in Experiment 1 was used to train the animals in Experiment 2. Following the last day on the VR 15 schedule of wheel-running reinforcement in the training phase, the rats were placed on a series of four tandem FR 1 VI schedules as part of another experimental procedure. The reinforcing consequence on these schedules was the opportunity to run for 30 s. After 90 days on this schedule, the animals were shifted to an FI 60-s schedule of wheel-running reinforcement for the present study. Reinforcer duration remained at 30 s. After 30 days on this schedule, the reinforcer duration for Rats B1, B2, B7, and B8 was shifted to 15 s, and the duration for Rats B5, B9, B10, and B12 was shifted to 90 s. Once the animals had experienced these durations for 30 days, the reinforcer duration for the rats on the 15-s duration was increased to 90 s and
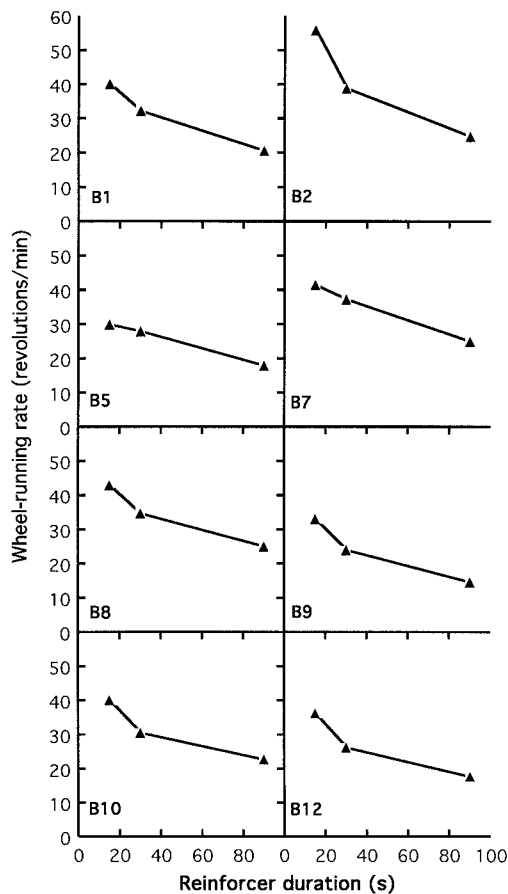
Fig. 5. Mean wheel-running rate (revolutions per minute) as a function of reinforcer duration for each rat. Mean values and standard errors were calculated from the last 10 sessions on each reinforcer duration.
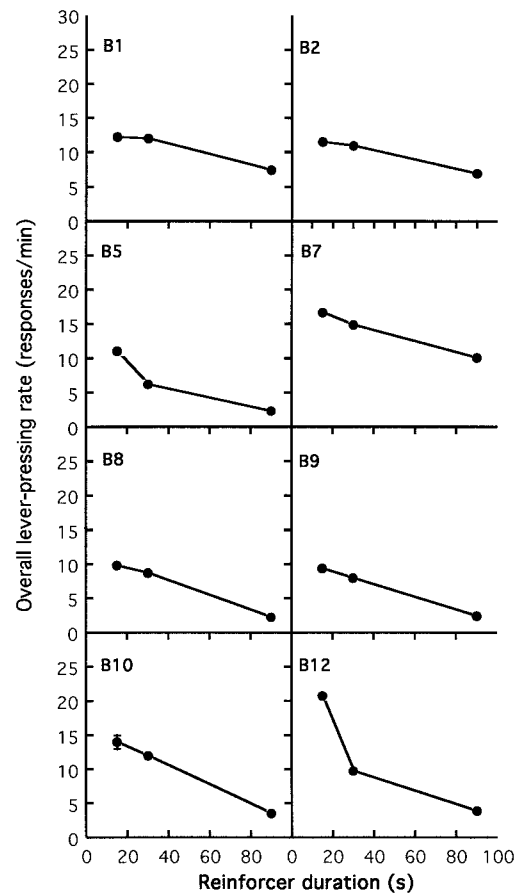

Fig. 6. Mean overall lever-pressing rate (responses per minute) as a function of reinforcer duration for each rat. Mean values and standard errors were calculated from the last 10 sessions on each reinforcer duration.

the duration for the rats on the 90-s duration was decreased to 15 s. Sessions were run between 9:00 a.m. and 2:00 p.m., 7 days a week. The same dependent variables described in Experiment 1 were measured and calculated in Experiment 2.

RESULTS

Figure 5 shows that mean wheel-running rates decreased for all rats as the duration of the opportunity to run increased. For the group, mean wheel-running rates for the 15-s, 30-s, and 90-s reinforcer durations were 39.86, 31.36, and 20.95 revolutions per minute, respectively. A repeated measures ANOVA revealed a significant effect of reinforcer duration, $F(2, 14) = 80.37$, $p < .0001$. Post hoc Dunnett t-test comparisons showed that

the differences between the 15-s and 30-s durations, $t(14) = 5.69$, $p < .01$, the 15-s and 90-s durations, $t(14) = 12.66$, $p < .01$, and the 30-s and 90-s durations, $t(14) = 6.96$, $p < .01$, were significant.

Figure 6 shows that mean overall lever-pressing rates for each animal likewise decreased as reinforcer duration increased. Mean overall lever-pressing rates for the 15-s, 30-s, and 90-s durations were 13.16, 10.30, and 4.84 responses per minute, respectively. A repeated measures ANOVA revealed a significant effect of reinforcer duration, $F(2, 14) = 28.14$, $p < .0001$. Comparisons using Dunnett t tests showed that overall lever-pressing rates were significantly different between the 15-s and 30-s durations, $t(14) = 2.54$, $p < .05$, the 15-s and 90-s durations, $t(14) = 7.38$, $p <$
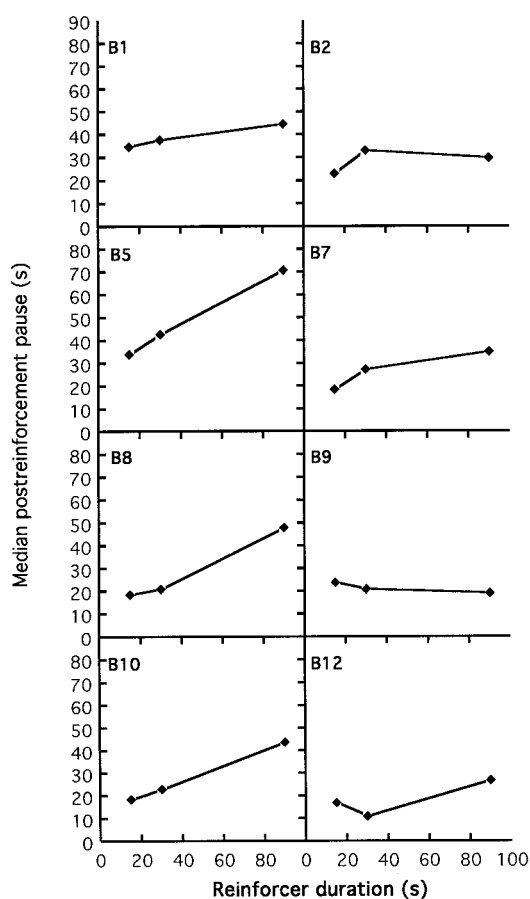
Fig. 7.   Median postreinforcement pause (in seconds) as a function of reinforcer duration for each rat. Median values were obtained for the pooled distribution of pauses from the last 10 sessions on each reinforcer duration.
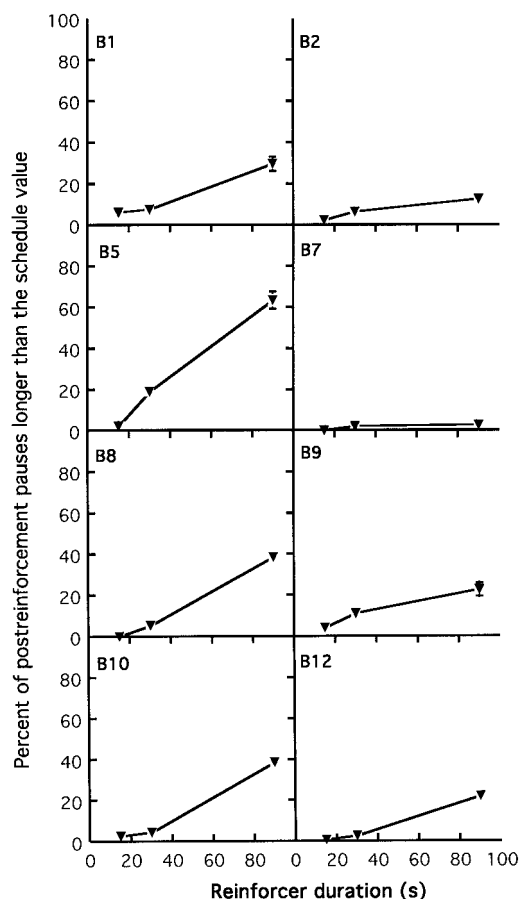

Fig. 8.   Mean percentage of intervals in which the postreinforcement pause was longer than the schedule value as a function of reinforcer duration for each rat. Mean values and standard errors were calculated from the last 10 sessions on each reinforcer duration.

.01, and the 30-s and 90-s durations, $t(14) =$ 4.85, $p < .01$.

Figure 7 shows median PRPs as a function of reinforcer duration for each animal. As reinforcer duration increased, median PRPs increased for 5 rats and decreased for 1 (Rat B9). For the remaining 2 rats, B2 and B12, the median PRP for the 30-s duration was longer than that at the 90-s duration for B2 and was shorter than that at the 15-s duration for B12. For the group, median PRPs for the reinforcer durations of 15 s, 30 s, and 90 s were 23.39, 26.95, and 39.60 s, respectively. A repeated measures ANOVA showed a significant effect of reinforcer duration, $F(2, 14) =$ 9.57, $p < .01$. Post hoc Dunnett t-test comparisons showed that differences between the 15- and 90-s durations, $t(14) = 4.16$, $p < .01$,

and the 30- and 90-s durations, $t(14) = 3.25$, $p < .05$, were significant.

Figure 8 shows that as the duration of the opportunity to run increased, the percentage of PRPs that were longer than the FI schedule value increased. This effect was apparent in the data for all rats except B7. For the 15-s, 30-s, and 90-s reinforcer durations, the mean percentages of PRPs longer than the schedule value were 2.22%, 7.22%, and 28.70%, respectively. A repeated measures ANOVA showed that there was a significant effect of reinforcer duration, $F(2, 14) = 16.08$, $p < .001$. Post hoc t-test comparisons revealed that the percentages of PRPs longer than the schedule value were significantly different between the 15-s and 90-s durations, $t(14) =$
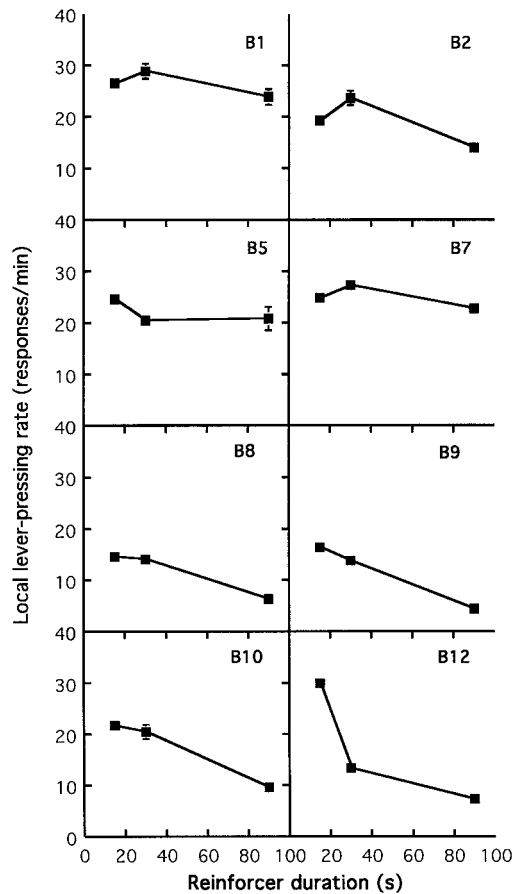
Fig. 9. Mean local lever-pressing rate (responses per minute) as a function of reinforcer duration for each rat. Mean values and standard errors were calculated from the last 10 sessions on each reinforcer duration.

5.34, $p < .01$, and the 30-s and 90-s durations, $t(14) = 4.33$, $p < .01$.

Figure 9 shows local lever-pressing rates as a function of reinforcer duration. For most rats, lever-pressing rates were lower at the 90-s duration than at the 15-s and 30-s durations; however, differences between the 15-s and 30-s durations were not significant. For the group, mean local lever-pressing rates for the 15-s, 30-s, and 90-s conditions were 22.24, 20.25, and 13.63 responses per minute, respectively. Statistical analysis revealed a significant reinforcer duration effect, $F(2, 14) = 9.37$, $p < .01$, and post hoc comparisons showed that the differences between the 15-s and 90-s durations, $t(14) = 4.13$, $p < .01$, and the 30-s and 90-s durations, $t(14) = 3.18$, $p < .05$, attained significance.

Finally, mean overall rates of reinforcement, not inclusive of reinforcer duration, for the 15-s, 30-s, and 90-s conditions were 57.89, 55.94, and 42.60 reinforcers per hour, respectively. These rates reflect the average time between the termination of one reinforcer duration and the onset of the subsequent reinforcer duration, which is largely a function of the schedule of reinforcement (i.e., FI 60 s). When reinforcer durations are included, the rates for these same conditions become 46.64, 38.15, and 20.63 reinforcers per hour. Mean session duration increased with reinforcer duration. For the 15-s, 30-s, and 90-s durations, mean session durations were 38.6, 47.2, and 87.3 min, respectively.

DISCUSSION

The effects of reinforcer duration on PRP duration, local lever-pressing rates, and wheel-running rates were consistent with those observed by Belke (1997) using tandem FR 1 VI schedules rather than FI schedules. Wheel-running rates, overall lever-pressing rates, and local lever-pressing rates decreased as reinforcer duration increased, and PRP duration increased as reinforcer duration increased. This replication of Belke's (1997) results shows that for wheel-running reinforcement, the effect of reinforcer duration on operant responding is not limited to response-initiated interval schedules.

In the present study, changes in PRP duration and local lever-pressing rates were less systematic than were changes in wheel-running rates. Differences in PRP duration and local lever-pressing rates between the lowest reinforcer durations were more variable. This result suggests that as reinforcer duration decreases, the magnitude of increases in local lever-pressing rates and decreases in PRP diminish. Consistent with this trend is Iversen's (1993) observation that changes in reinforcer duration between 15 and 4 s on FR and FI schedules did not produce appreciable or consistent effects on operant responding.

GENERAL DISCUSSION

Previous research has shown that both schedule value and reinforcer magnitude influence PRP duration on FI schedules. As FI schedule value increases, PRP duration increases. Likewise, as reinforcement magni-

tude increases, PRP duration increases. In the present study, only the latter relation was observed. Contingent wheel running generated long PRPs that in many cases exceeded the schedule value. The duration of the pause was a direct function of the duration of the running bout. These long PRPs appear to be an effect of the reinforcer per se, perhaps a momentary satiation-like effect rather than an effect of the schedule. As such, the long PRPs rendered the manipulation of the schedule value over the range of values investigated ineffective.

Furthermore, such effects may also account for the inverse relation between local lever-pressing rates and the duration of the running bout. Local lever-pressing rates decreased rather than increased as the duration of the contingent running bout increased. As noted by Belke (1997), this relation appears to be inconsistent with the prediction that response rates should increase with reinforcement magnitude. However, if inhibitory aftereffects influence both the duration to the first postreinforcement lever press and subsequent interresponse times, then a decline in response rates with an increase in the inhibitory aftereffect may well occur.

In any case, the present results illustrate the importance of taking such effects into account when attempting to study schedule effects or the strengthening effects of reinforcers. The usual practice of using small bits of food or water as reinforcers minimizes such complicating effects. But such effects may play an important role when we use other kinds of reinforcers or unusually large values of food or water reinforcers.

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